

JAN 16 1947

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
April 1942 as
Restricted Bulletin

CALCULATION OF TAB CHARACTERISTICS FOR FLIGHT

CONDITIONS FROM WIND-TUNNEL DATA

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National Advisory Committee for Aeronautics
Washington, D. C.
January 16, 1947



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RESTRICTED BULLETIN

CALCULATION OF TAB CHARACTERISTICS FOR FLIGHT
CONDITIONS FROM WIND-TUNNEL DATA

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Certain tail-surface characteristics calculated from wind-tunnel data have been reported not to check with flight-test measurements. This discrepancy might have been caused by failure to account for the changes in equilibrium conditions that occurred in flight when the wind-tunnel data measured in static-force tests were applied.

The problem under consideration is the calculation of the effect of tab deflection upon the free-floating angle of the elevator, as in a servocontrol. Flight-test measurements are reported to have shown nearly twice as great a change in elevator deflection per degree tab deflection as wind-tunnel tests have indicated. The following illustration may be given in order to show that such a discrepancy may be expected if the tab characteristics are computed without consideration of the response of the airplane to a deflection of the elevator.

It can be shown that, for zero pitching velocity, the hinge-moment coefficient of the elevator may be expressed by the following relation:

$$C_{he} = C_{he\alpha'} \alpha' + C_{he\delta_e} \delta_e + C_{he\delta_t} \delta_t$$

or

$$C_{he} = C_{he\alpha'} (\alpha_0 + \epsilon_t) + C_{he\delta_t} \delta_t \\ + \left[C_{he\delta_e} + C_{he\alpha'} \frac{\partial \alpha}{\partial \delta_e} (1 - \epsilon_a) \right] \delta_e$$

where

 α' angle of attack of tail α angle of attack of airplane

α_0 angle of attack of airplane at zero lift

i_t angle of incidence of tail

δ_e elevator deflection

δ_t tab deflection

ϵ angle of downwash

C_{h_e} elevator hinge-moment coefficient

and

$$C_{h_e \alpha'} = \frac{\partial C_{h_e}}{\partial \alpha'}$$

$$C_{h_e \delta_e} = \frac{\partial C_{h_e}}{\partial \delta_e}$$

$$C_{h_e \delta_t} = \frac{\partial C_{h_e}}{\partial \delta_t}$$

$$\epsilon_\alpha = \frac{\partial \epsilon}{\partial \alpha}$$

Thus, when $C_{h_e} = 0$, the free-floating angle of the elevator is

$$\delta_{e \text{free}} = - \frac{C_{h_e \alpha'} (\alpha_0 + i_t) + C_{h_e \delta_t} \delta_t}{C_{h_e \delta_e} + C_{h_e \alpha'} (1 - \epsilon_\alpha) \frac{\partial \alpha}{\partial \delta_e}}$$

The rate of change of free-floating angle of the elevator with tab deflection is

$$\left(\frac{\partial \delta_e}{\partial \delta_t} \right)_{\text{free}} = - \frac{C_{h_e \delta_t}}{C_{h_e \delta_e} + C_{h_e \alpha'} (1 - \epsilon_\alpha) \frac{\partial \alpha}{\partial \delta_e}}$$

From reference 1, it can be seen that, for typical airplanes, $\frac{\partial \delta_e}{\partial \alpha}$ lies between 0 and -1.0 and has a recommended value of -0.5. It should be noted that the sign of δ_e is taken opposite to that used in reference 1. For airplane 3 of reference 1, with various center-of-gravity positions

$$\frac{\partial \alpha}{\partial \delta_e} = \frac{1}{\frac{\partial \delta_e}{\partial \alpha}} = -1.08, -2.22, -2.85$$

From reference 2, the section parameters for an NACA 0009 airfoil with a 0.30c flap are:

$$C_{he_{\alpha t}} = -0.0075$$

$$C_{he_{\delta_e}} = -0.0130$$

$$C_{he_{\delta_t}} = -0.0094 \text{ for a } 0.10 c_e \text{ tab}$$

$$= -0.0130 \text{ for a } 0.20 c_e \text{ tab}$$

$$= -0.0160 \text{ for a } 0.30 c_e \text{ tab}$$

$$\text{Assume } \frac{\partial \epsilon}{\partial \alpha} = 0.6$$

$$\text{Thus, for a } 0.20 c_e \text{ tab, when } \frac{\partial \alpha}{\partial \delta_e} = -2.22$$

$$\frac{\partial \delta_e}{\partial \delta_t} = - \frac{-0.0130}{(-0.0130) + (-0.0075)(1 - 0.6)(-2.22)} = -2.06$$

The curves of figure 1 have been computed in this manner. They give the parameter $\frac{\partial \delta_e}{\partial \delta_t}$ for various amounts of the airplane response factor $\frac{\partial \alpha}{\partial \delta_e}$. Thus, it can be seen

that the reported discrepancy between computed results and the flight-test measurements might well be explained if the computation neglected the response of the airplane to elevator movement. Such computations would be represented by the points at $\frac{\partial \alpha}{\partial \delta_e} = 0$.

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2. Ames, Milton B., Jr., and Sears, Richard I.: Determination of Control-Surface Characteristics from NACA Plain-Flap and Tab Data. Rep. No. 721, NACA, 1941.

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Fig. 1

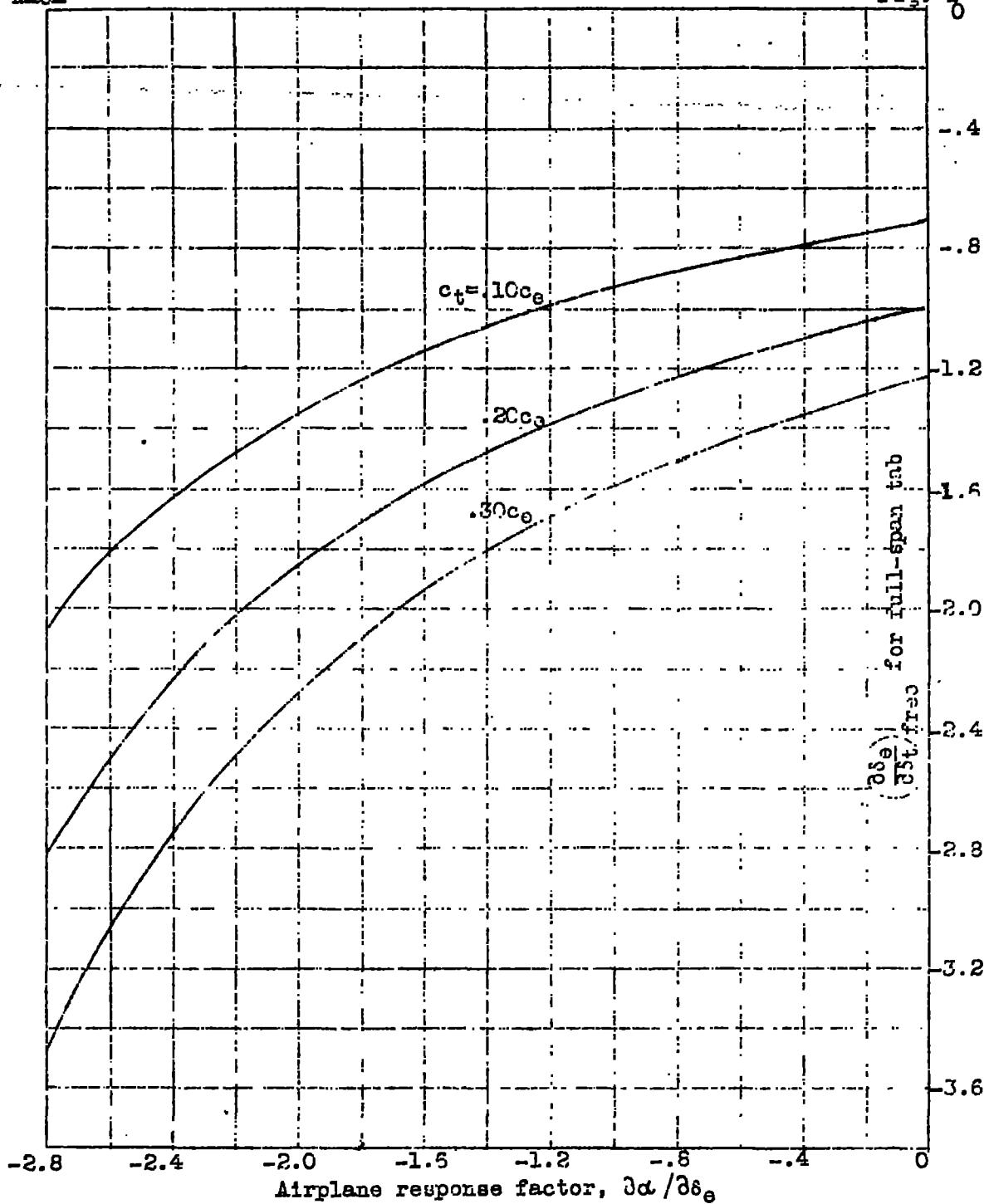


Figure 1.- Variation of tab effectiveness with airplane response to elevator deflection. NACA 0009 airfoil 0.30c elevator.

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